Evaluating the effect of 3D urban form on neighborhood land surface temperature using Google Street View

Central Arizona-Phoenix Long-Term Ecological Research CAP LTER

Y. Zhang[1], A. Middel[2, 3], B.L. Turner II[1, 4]

[1]School of Geographical Sciences and Urban Planning, Arizona State University
[2]School of Arts, Media and Engineering, Arizona State University
[3]School of Computing, Informatics, and Decision Systems Engineering, Arizona State University
[4]Julie Ann Wrigley Global Institute of Sustainability, Arizona State University

ASU School of Geographical Sciences & Urban Planning, Arizona State University

Introduction

Incorporating the vertical urban form in surface temperature assessments is important, because shading effects are not well captured in traditional planar view remote sensing data. The impact of vertical urban forms on land surface temperature (LST) has not been sufficiently addressed due to a lack of high-resolution urban form data [3, 4].

To fill this gap, this study employs a novel spherical urban fraction metric derived from segmented 360° Google Street View (GSV) imagery [2]. Google provides an immense collection of Street View images, enabling city-wide fine-scale measurements to address vertical urban form dimensions. The study area is the city of Phoenix, AZ which is made up of 1,339 census block groups. In this study, we:

1. Compared the novel GSV spherical fractions [2] with the planar land cover fractions derived from high resolution aerial imagery [1].
2. Examined the relationships of the two datasets with LST using correlation and linear regression analysis.
3. Developed robust global and local models to explain the LST variations by integrating spherical, planar and social variables.

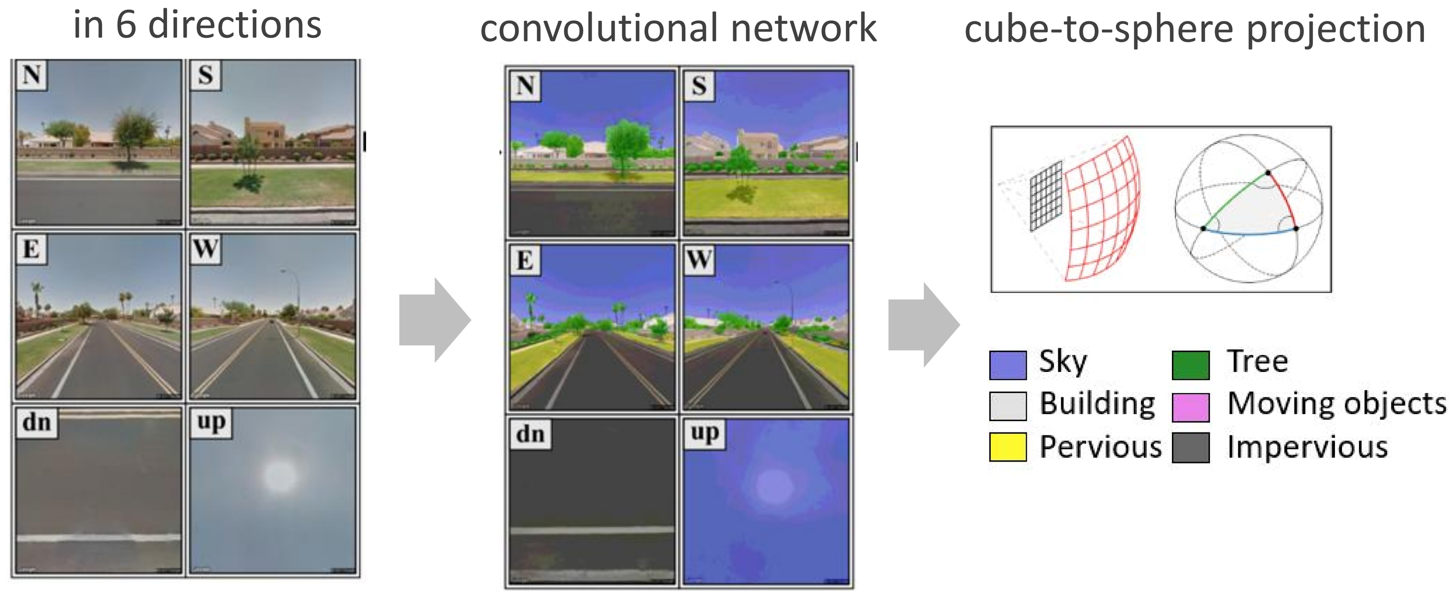
Data

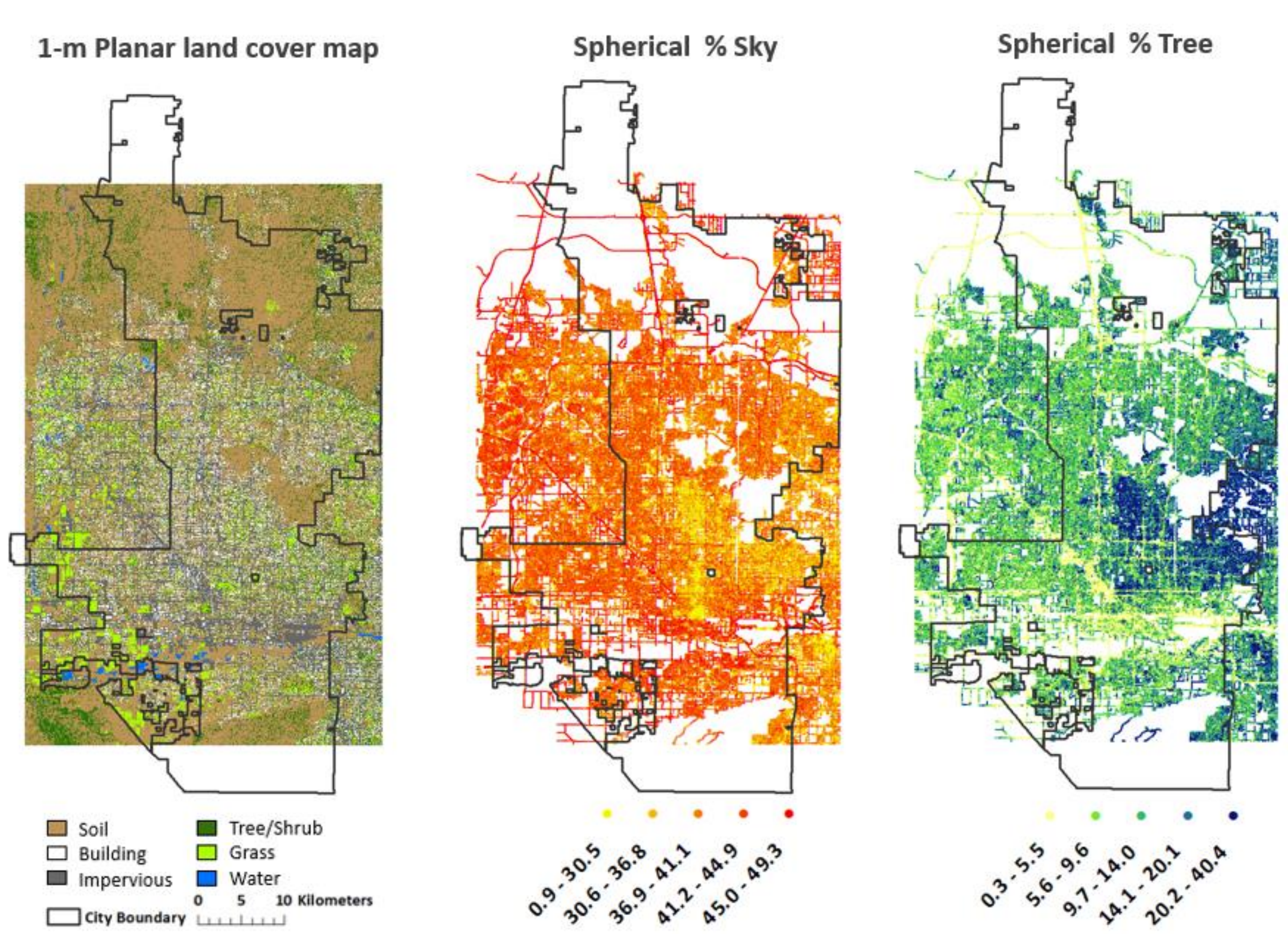
Google Street View Image Classification

(1) 90° Field of view images from Google Street View in 6 directions

(2) Image classification using fully convolutional network

(3) Calculate the percentage of each class based on a cube-to-sphere projection





Method and Results

1. Comparisons between the Spherical and Planar Fractions at Census Tract Level

Fig. 1 Boxplots of the Spherical and Planar Fractions

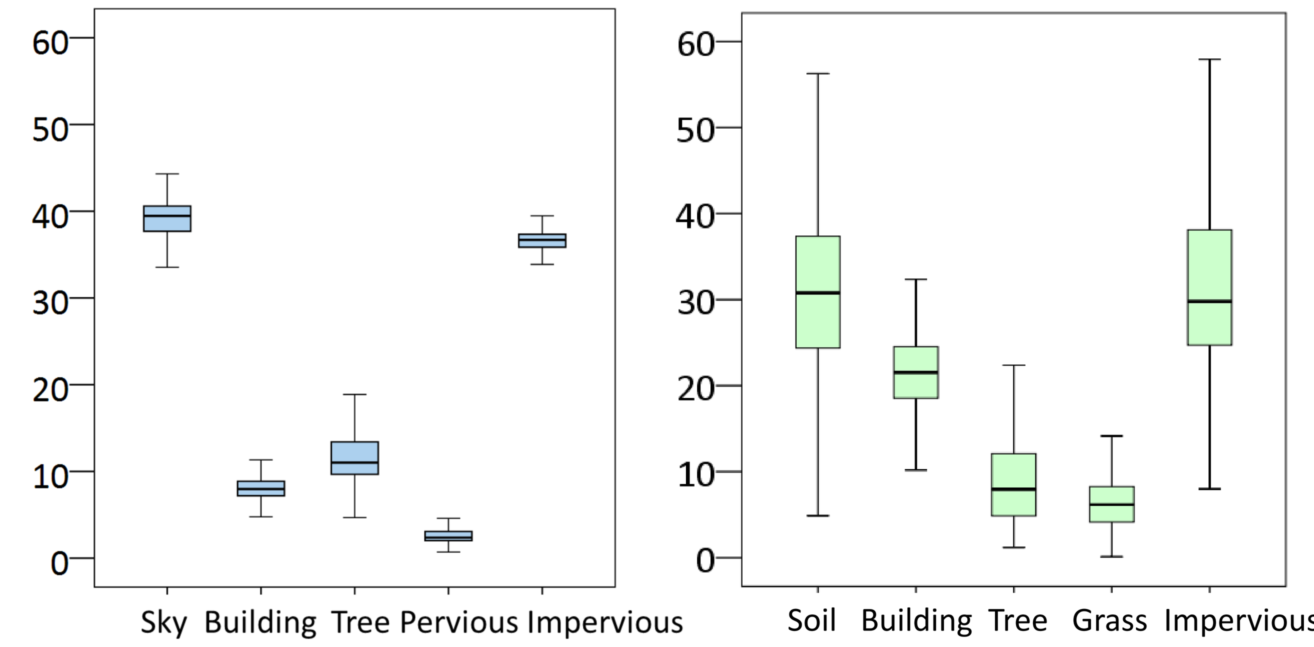
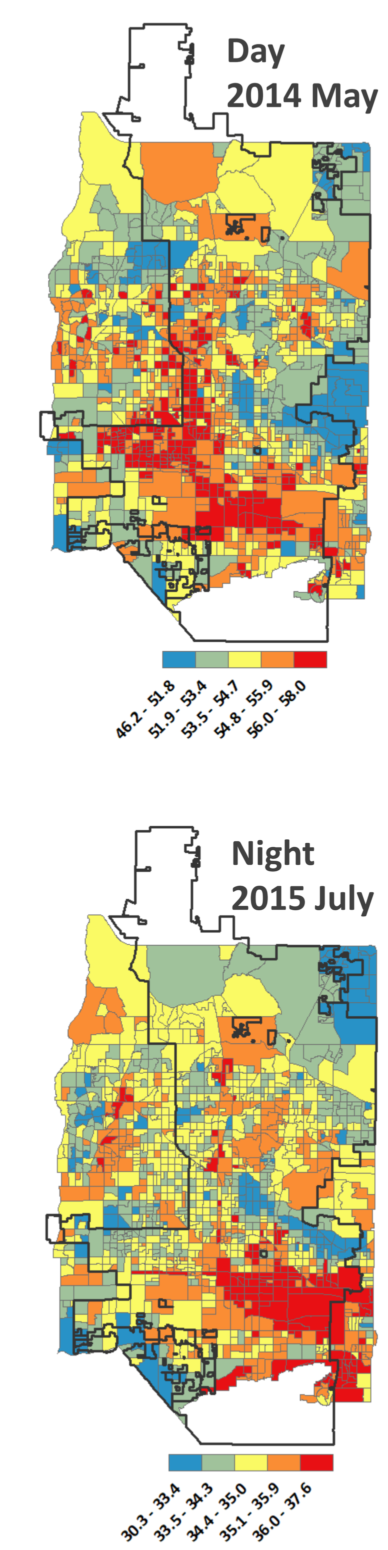


Table 1 Paired T-Test

	Spherical mean	Planar mean	Correlation Coeff.	Paired Differences Mean	Paired Differences Std. Deviation
Building	8.0	22.1	.11	-14.1**	5.5
Tree	12.0	9.1	.43**	2.9**	5.3
Impervious	36.4	31.3	.30**	5.0**	11.9

** Significant at 0.01 level

ASTER LSTs



2. Correlation and Global Regression Analysis with Land Surface Temperature (Day and Night)

Table 2 Pearson's Correlation Coefficients with LST

Spherical Fraction	Day LST	Night LST	Planar Fraction	Day LST	Night LST
Sky	.52**	.11*	Soil	.09**	-.22**
Building	.21**	.32**	Building	.08**	-.15**
Tree	-.58**	-.35**	Tree	-.48**	-.31**
Pervious	-.46**	-.47**	Grass	-.35**	-.28**
Impervious	.34**	.37**	Impervious	.23**	.51**

** Significant at 0.01 level, * Significant at 0.05 level.

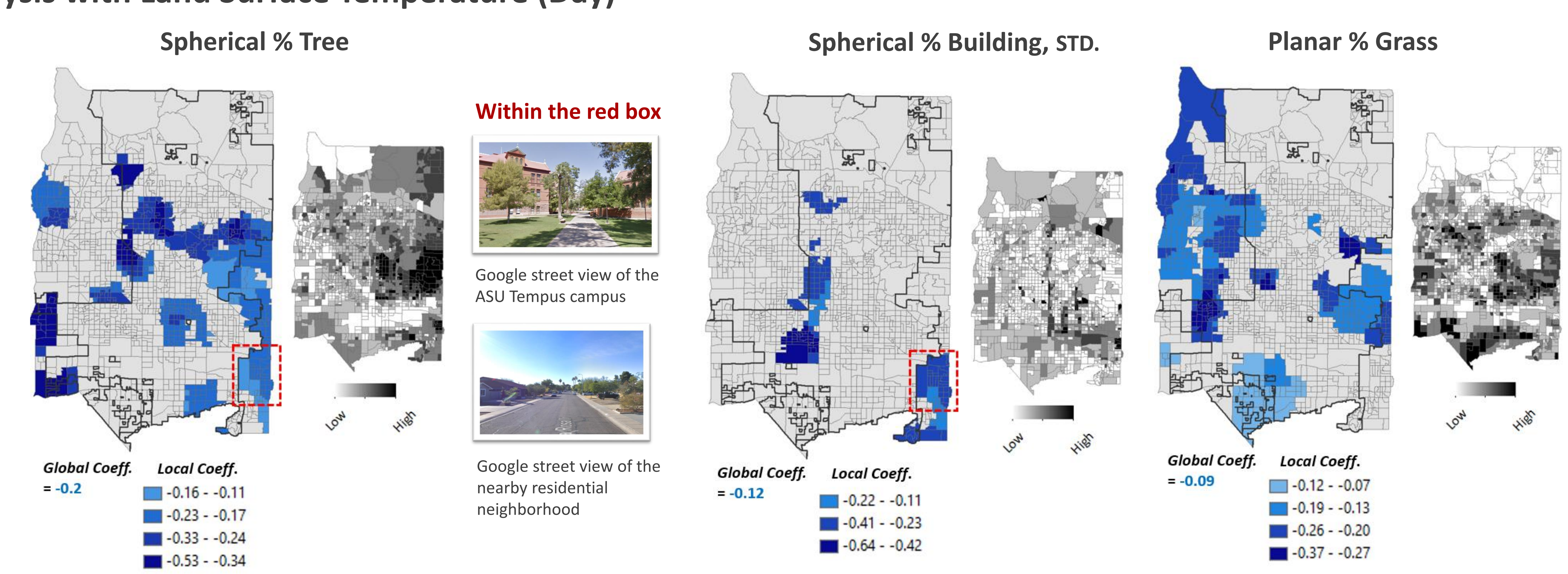
Table 3 Global Regressions with LST

Global Regression		Spherical	Planar	Spherical + Planar	Spherical + Planar + Social
Day	R^2	.31	.36	.46	.60
	Adj. R^2	.31	.36	.46	.59
Night	R^2	.31	.32	.43	.43
	Adj. R^2	.31	.32	.42	.43

3. Local Regression Analysis with Land Surface Temperature (Day)

Table 4 Comparisons of Global and Local Regressions

Day LST	Global Model	Local Model
R^2	.60	.80
AICc	4081	3733
Moran's I	.1**	.001
Residual Pattern	Clustered	Random



Findings

1. The spherical factions have less variations compared to planar fractions, because they are biased towards street views.
2. Adding spherical fractions from Google Street View imagery, daytime and nighttime LSTs in Phoenix are predicted more accurately, compared to the planar land cover factions. In addition, the geographically weighted regression further improved the model fit versus the ordinary least square regression method; the R^2 increased from 0.6 to 0.8.
3. The geographically weighted regression coefficient maps feature the places where certain urban form changes are especially effective for heat mitigation, supporting the search for the optimal urban form design of desert cities.

Acknowledgements

This research was supported by the Central Arizona-Phoenix Long-Term Ecological Research program (NSF Grant No. BCS-1026865), National Science Foundation (NSF) under Grant No. SES-0951366, NSF DNS Grant No. 1419593 and USDA NIFA Grant No. 2015-67003- 23508, the Julie Ann Wrigley Global Institute of Sustainability. The research was undertaken in the Environmental Remote Sensing and Geoinformatics Lab, Arizona State University.

References

1. Li, X., Myint, S. W., Zhang, Y., Galletti, C., Zhang, X., & Turner II, B. L. 2014. Object-based land-cover classification for metropolitan Phoenix, Arizona, using aerial photography. *International Journal of Applied Earth Observation and Geoinformation*, **33**, 321-330.
2. Middel, A., Lukasczyk, J., Zakrzewski, S., Arnold, M., & Maciejewski, R. 2019. Urban form and composition of street canyons: A human-centric big data and deep learning approach. *Landscape and Urban Planning*, 183, 122-132.
3. Middel, A., J. Lukasczyk and R. Maciejewski. 2017. Sky view factors from synthetic fisheye photos for thermal comfort routing - a case study in Phoenix, Arizona. *Urban Planning* **2**(1):19-30.
4. Turner II, B.L., 2016. Land system architecture for urban sustainability: new directions for land system science illustrated by application to the urban heat island problem. *Journal of Land Use Science* **11**(6) 689-697.